

Using 20th Century Reanalysis Data to Examine Northern Hemisphere Storm Track Trend in the 20th Century

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 - Assessing the Quality of Synoptic Scale Variability Derived from the 20th Century Reanalysis Project



NOAA

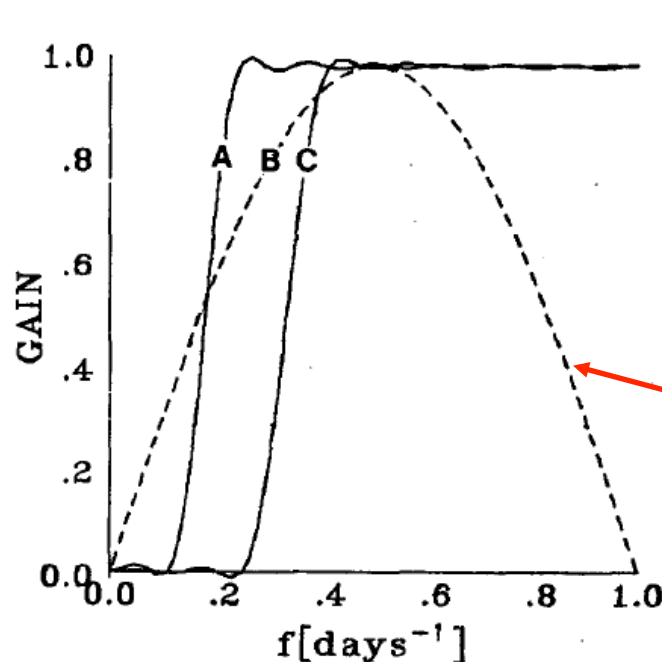
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Motivation

- Several studies have suggested that NH storm track activity has increased between 1950 and 1999, mostly based on NCEP-NCAR reanalysis data:
 - Graham and Diaz (2001): Pacific cyclone activity
 - Geng and Sugi (2001): Atlantic variance statistics
 - Chang and Fu (2002): NH variance statistics
- However, more recent studies have suggested that NCEP-NCAR and ERA40 may have spurious trends due to change in observing system
 - Harnik and Chang (2003): Compared NCEP-NCAR reanalysis to rawinsonde observations
 - Chang (2007): Compared NCEP-NCAR and ERA40 reanalyses to ship observations
 - Bengtsson et al. (2004): Spurious jumps in kinetic energy in ERA40 in the 1970s due to introduction of satellite data
- NOAA's 20th Century reanalysis, using surface obs only, is expected to contain less of a spurious trend
 - Question: Is this true?
 - Question: Can we use 20th Century reanalysis data to assess the trend not just between 1950-1999, but for the entire 20th Century?

- Storm Track Activity:
 - Variance computed using a 24-hr difference filter (Wallace et al 1988)

$$V_{1df} = \overline{[v(t + 24hr) - v(t)]^2}$$

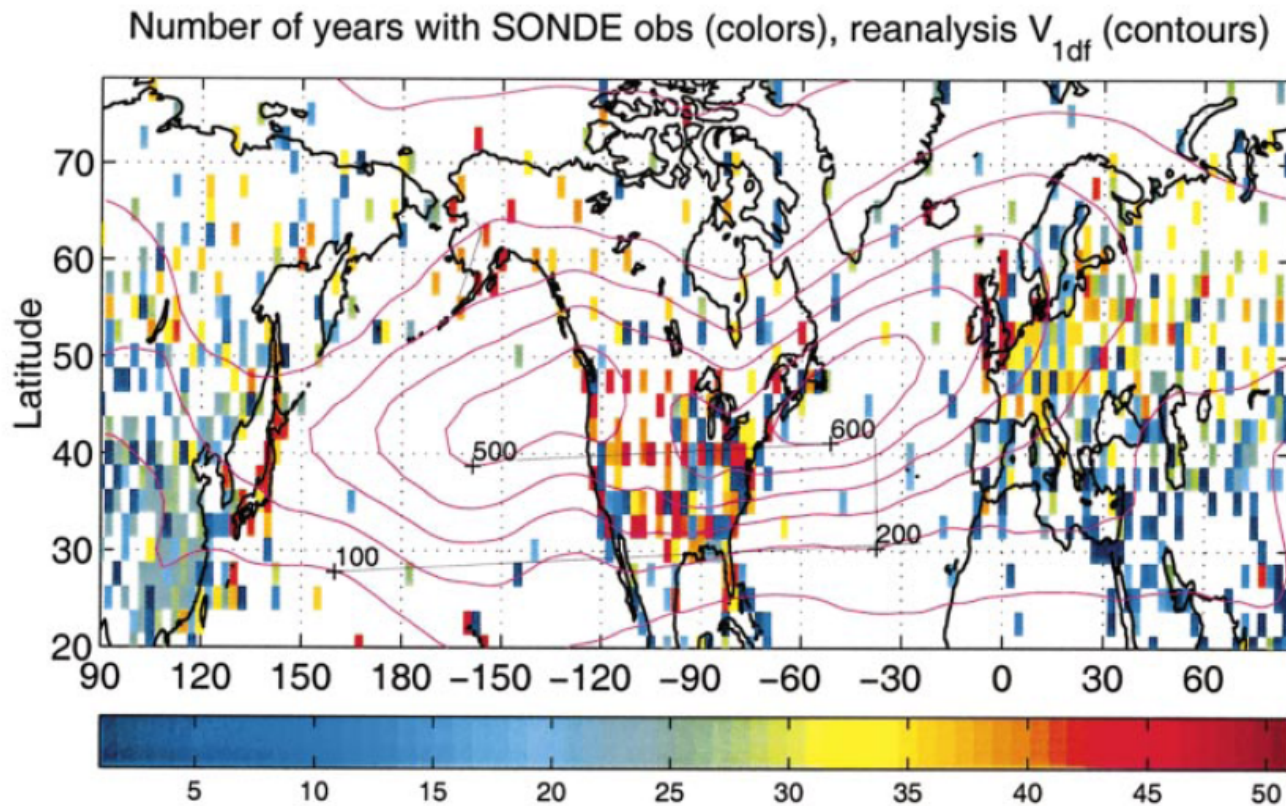


Meridional wind variance at 300 hPa (near tropopause)

Curve B (dashed line) shows the response of the 24-hr difference filter as a function of frequency.

Note: $\frac{1}{2}$ power point at periods of 1.2 and 6 days

FIG. 2. Response functions of the filters used in this study. The two highpass filters have half-power points near frequencies of 0.18 day^{-1} (A) and 0.33 day^{-1} (C). The 24-hour differences are divided by two in order to make the maximum frequency response of B equal to unity.

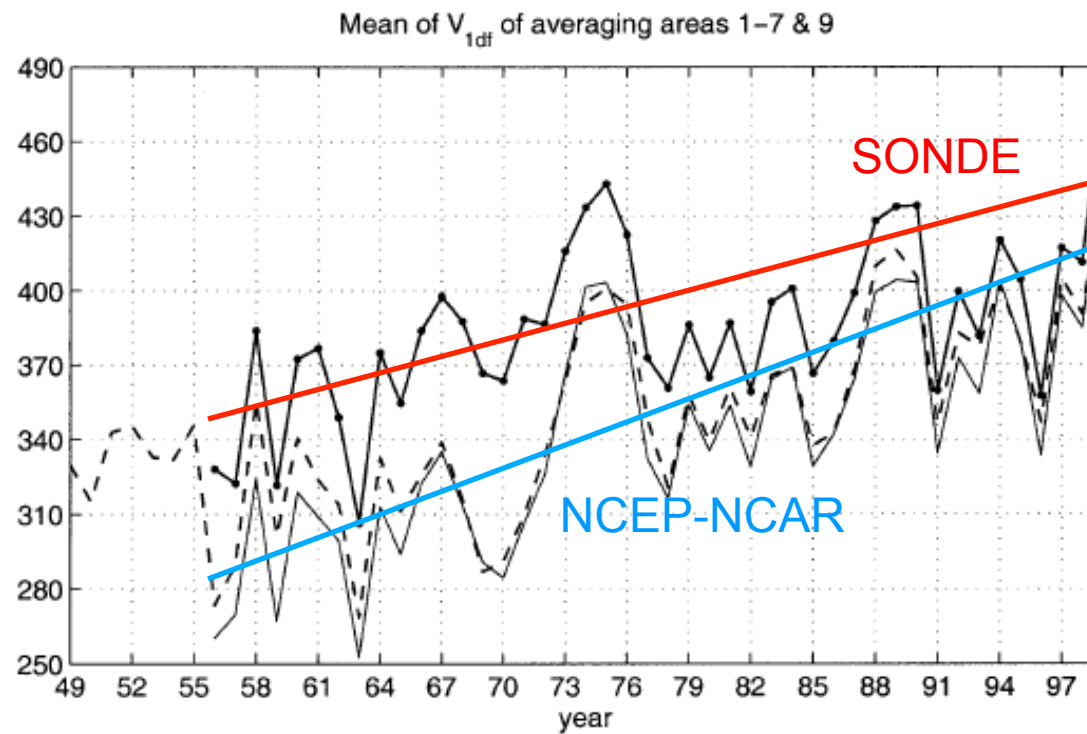
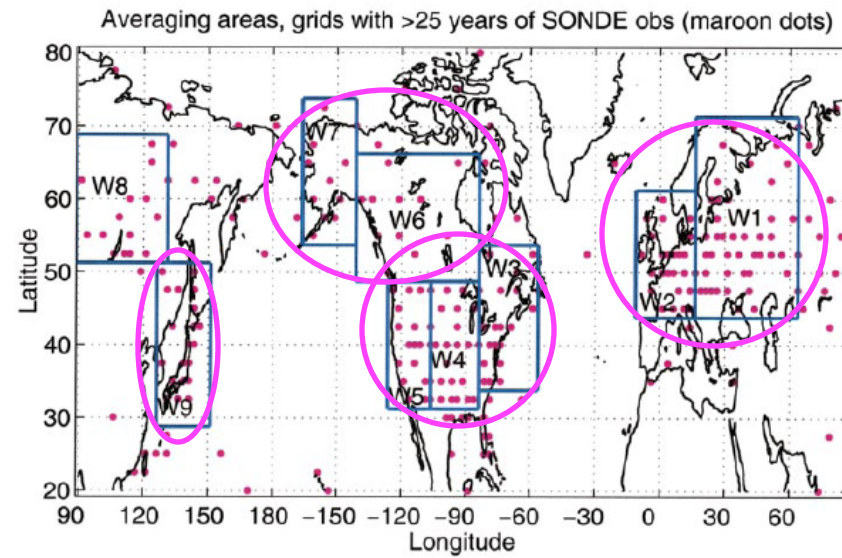


Contours: Climatological V_{1df} (DJF 1948/49-1998/99)
based on NCEP-NCAR reanalysis

Colored grid boxes: Number of years with sufficient
rawinsonde observations within that box

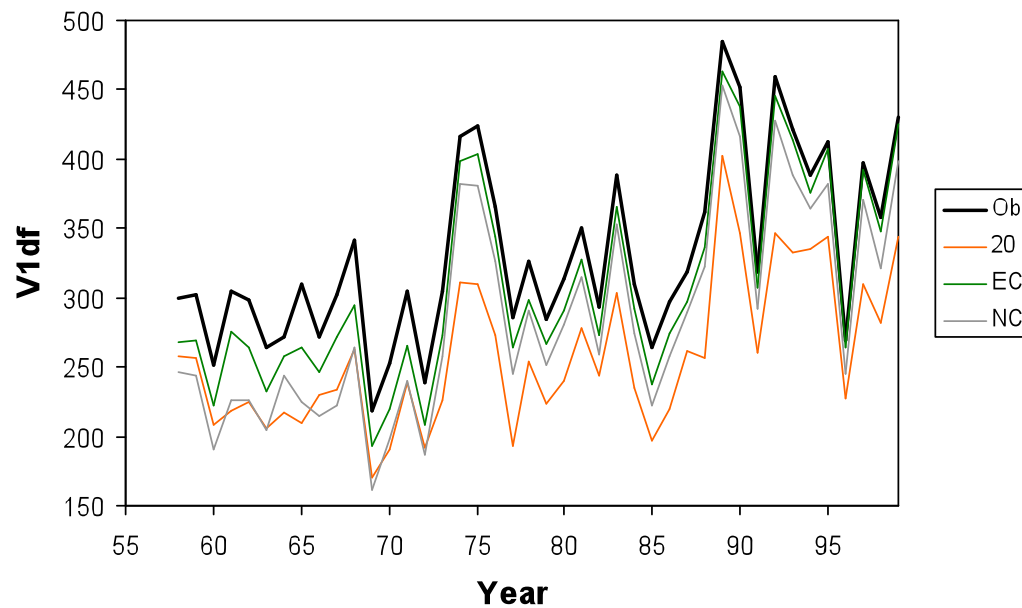
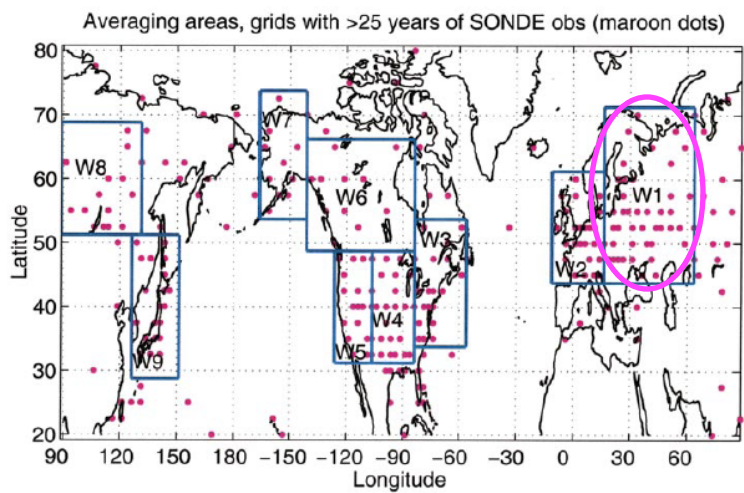
Harnik and
Chang (2003)

Harnik and Chang
(2003)



Methodology

- In this study, the method used by Harnik and Chang (2003) is applied and extended to examine storm track trend in 3 reanalysis datasets:
 - NCEP-NCAR (NC), ERA40 (EC), and 20th Century (20)
 - 6-hrly data from DJF 1957/58 to 1998/99 (42 winters)
 - All data interpolated onto same 2.5x2.5 lat-lon grid
 - Observations (Ob): Rawinsonde v at 300 hPa obtained from NCEP-NCAR reanalysis observation data archive
 - Observations also gridded onto same 2.5x2.5 grid
 - Observed v is QC'ed by trimming at each grid point using climatology $\pm 4\sigma$ based on ERA40 (similar to COADS trimming)

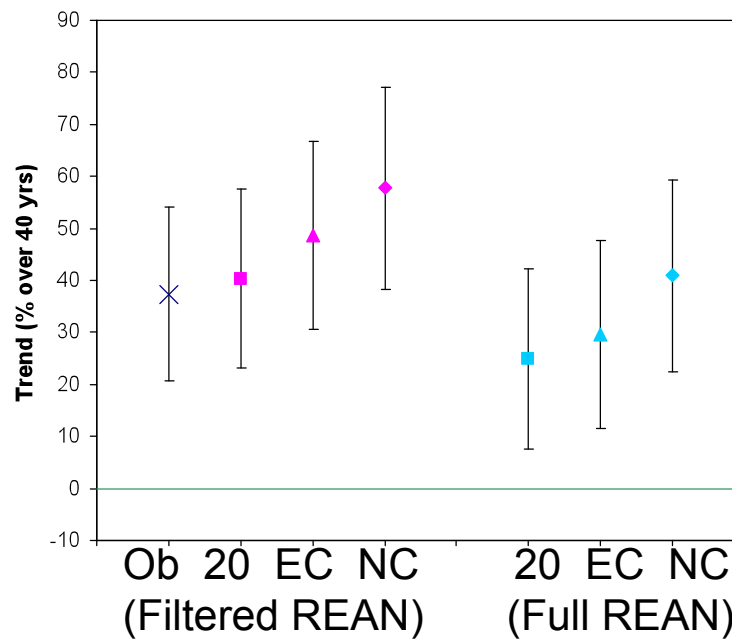


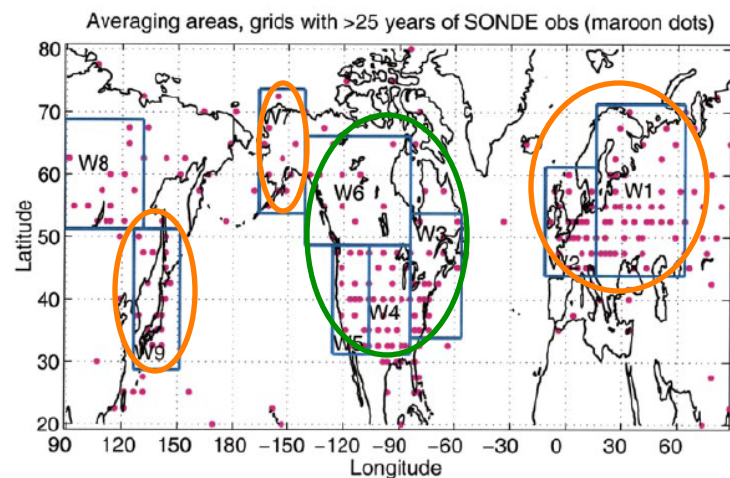
×: Observations (Ob)

Magenta: REAN filtered
by Obs

Cyan: Full REAN

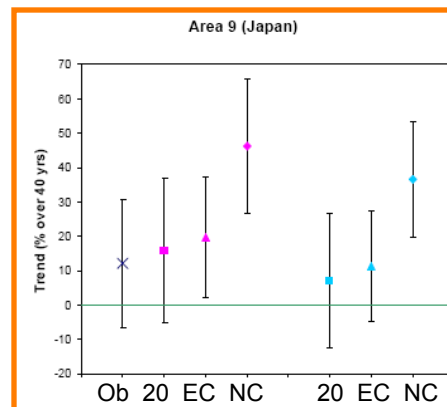
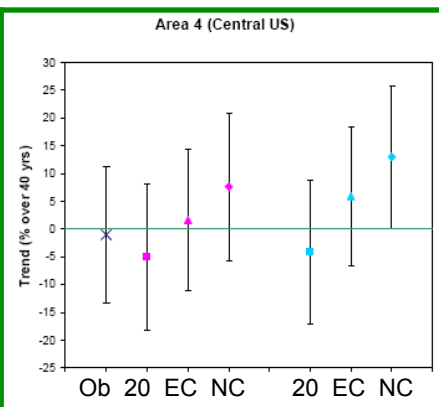
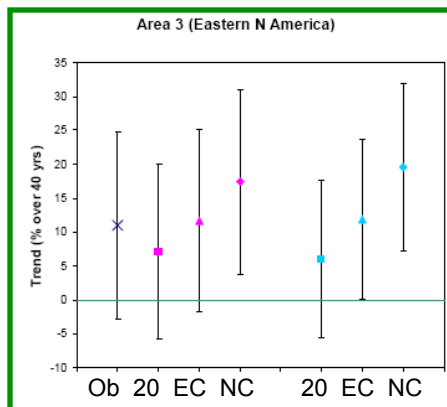
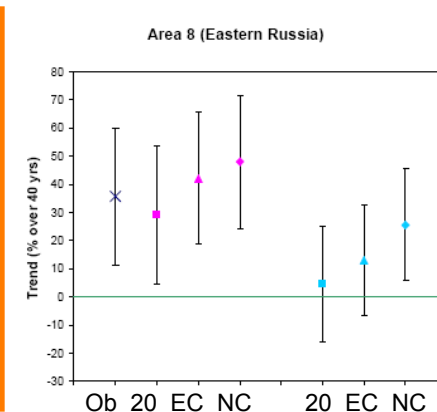
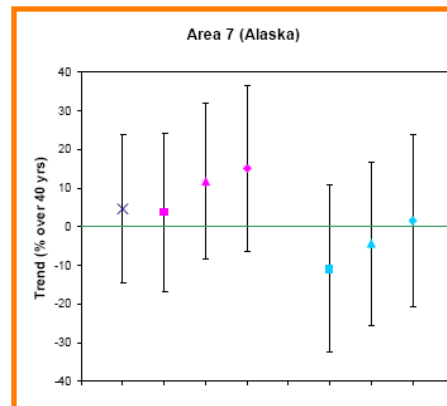
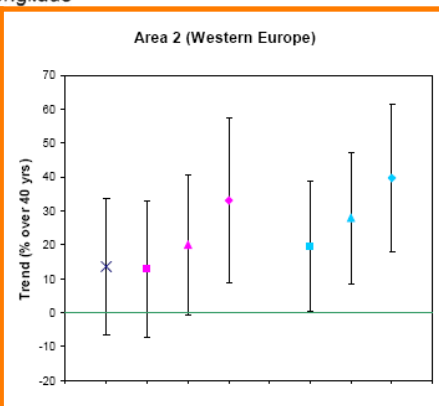
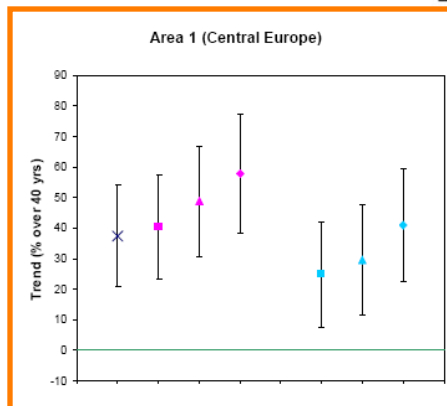
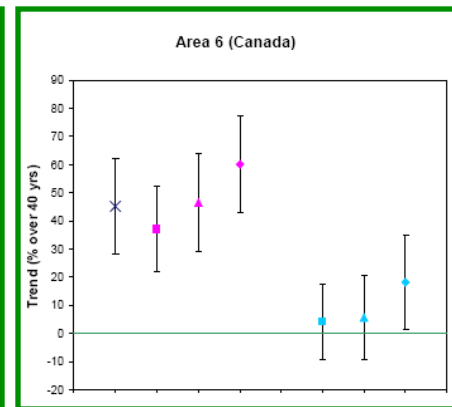
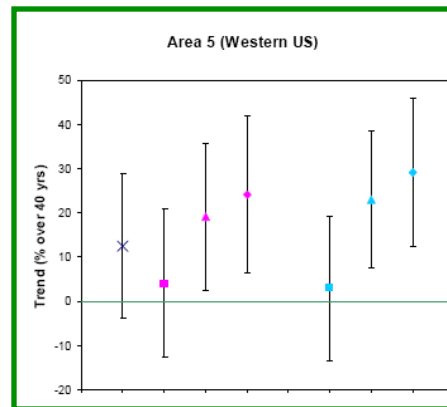
Area 1 (Central Europe)





Orange: 20CR most consistent with Obs

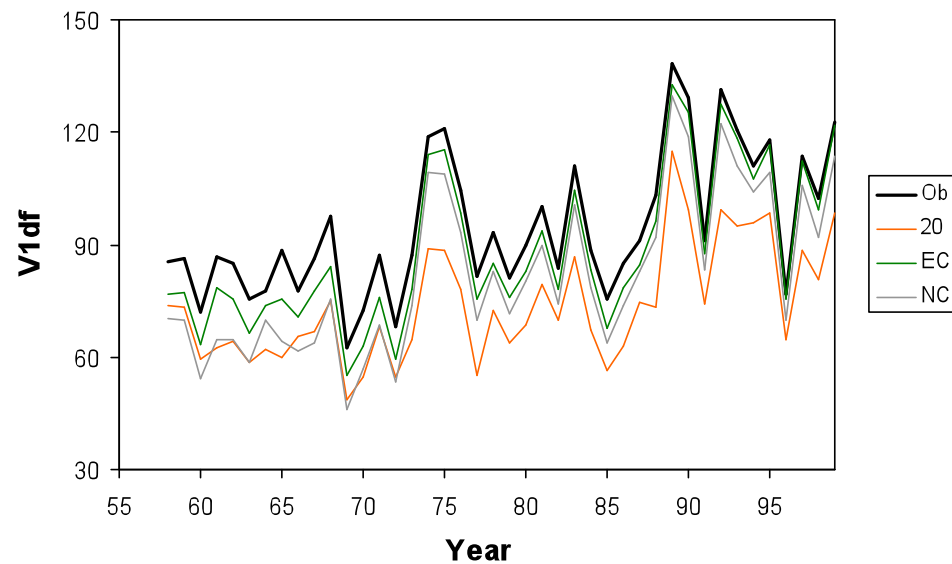
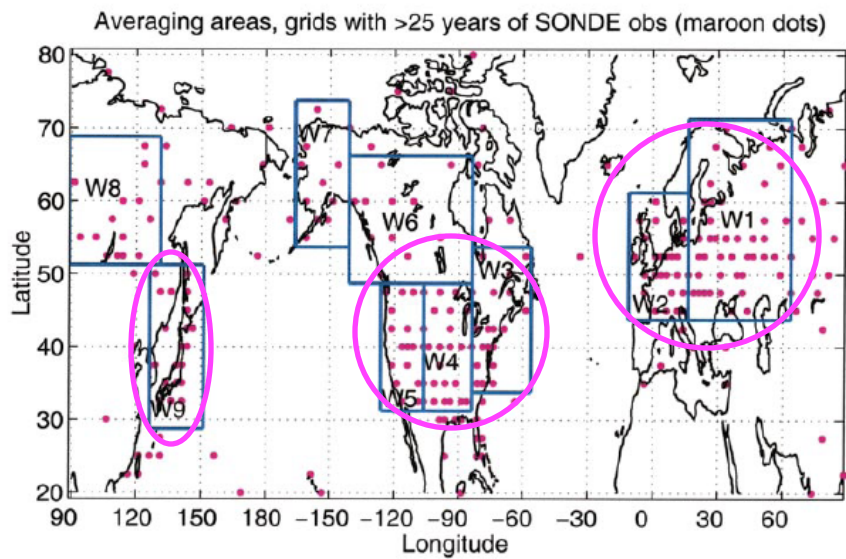
Green: ERA40 most consistent with Obs



x: Observations

Magenta: REAN filtered by Obs

Cyan: Full REAN

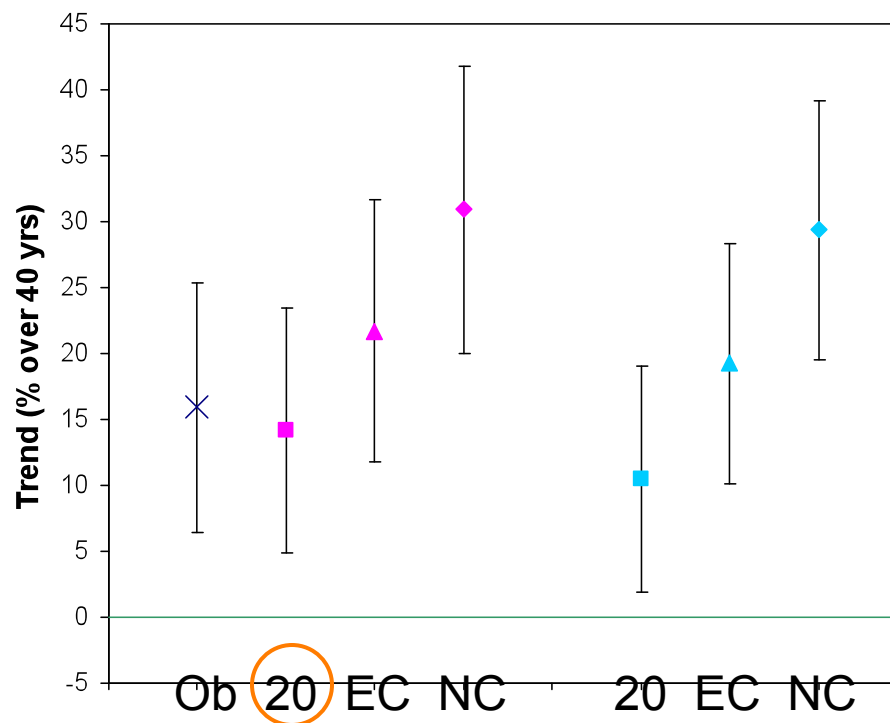


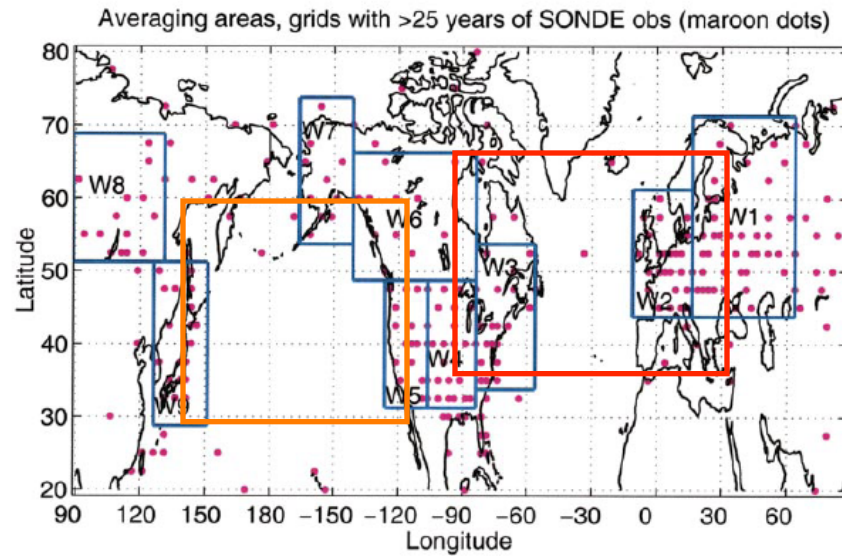
Average of Areas 1-5 and 9

×: Observations

Magenta: REAN filtered
by Obs

Cyan: Full REAN





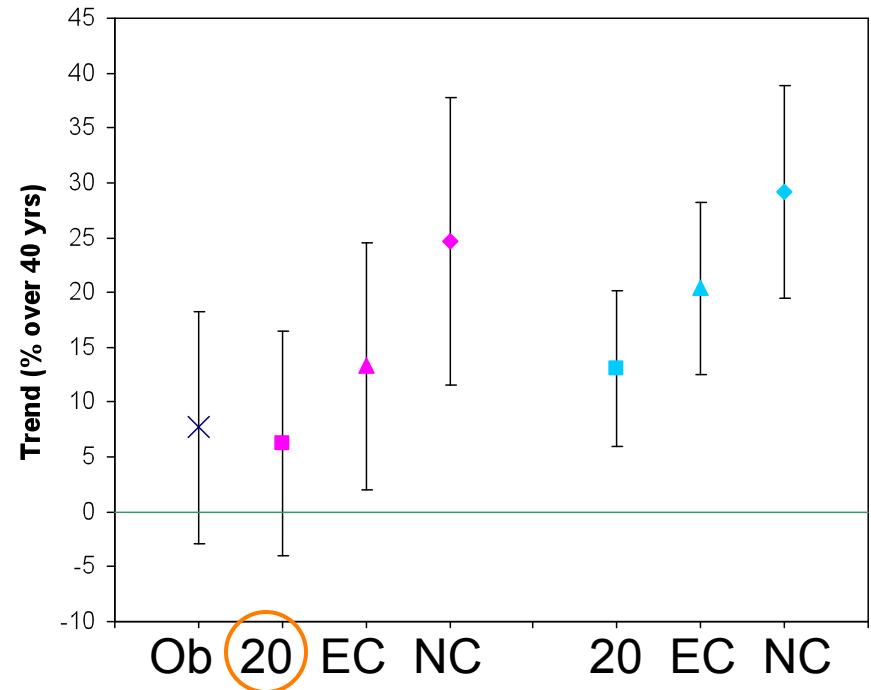
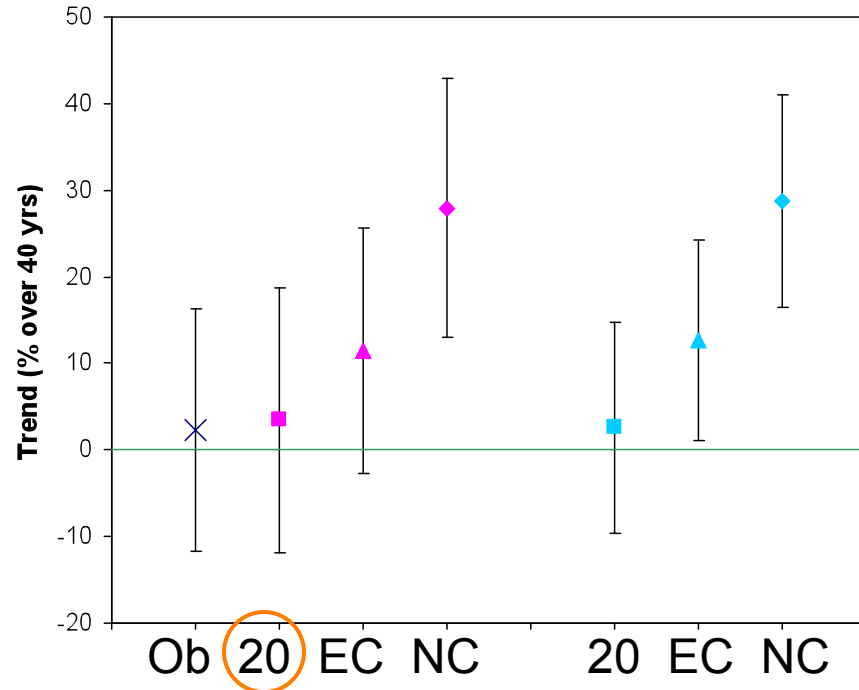
×: Observations

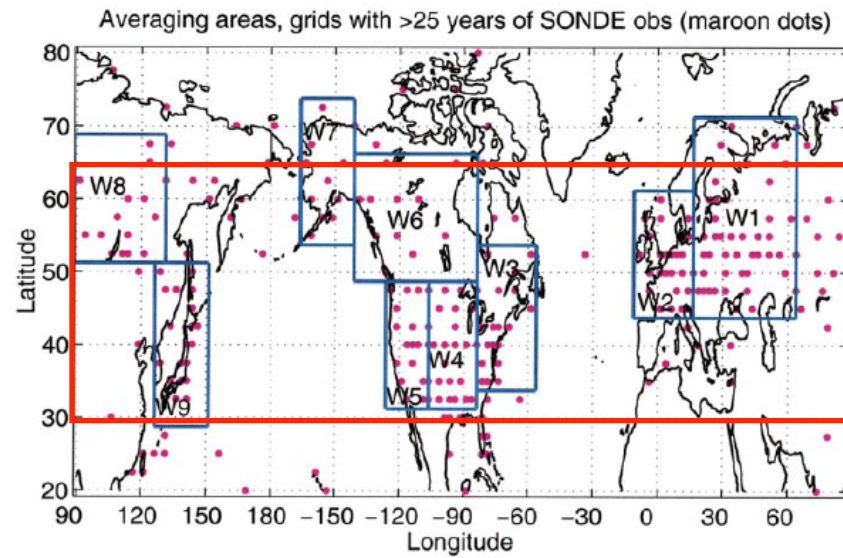
Magenta: REAN filtered
by Obs

Cyan: Full REAN

Pacific (140E-120W, 30-60N)

Atlantic (90W-30E, 35-65N)



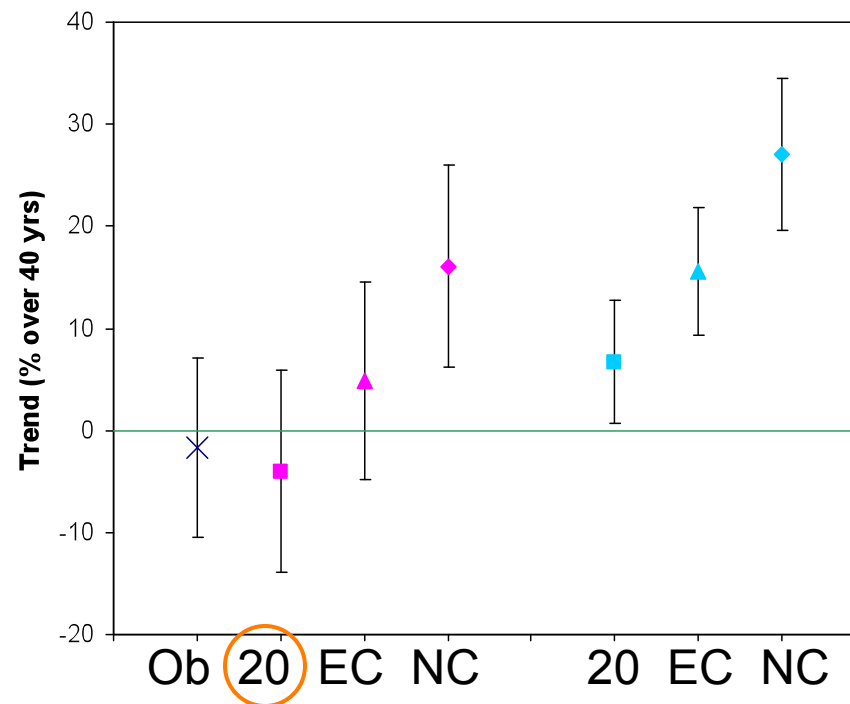


Northern Hemisphere (30-65N)

×: Observations

Magenta: REAN filtered
by Obs

Cyan: Full REAN



Summary

- 300 hPa V1df derived from 3 reanalysis datasets have been directly compared to those derived from rawinsonde observations
 - Note that rawinsonde 300 hPa V is assimilated by NNR and ERA40, but not by 20CR
 - Despite this, in 4 out of 9 regions (over Europe, Alaska, and Japan) trend based on 20CR most consistent with Obs
 - In 4 regions (over US and Canada), trend based on ERA40 most consistent with Obs
 - Trend based on NNR consistently biased high compared to Obs, and is most inconsistent in all 9 regions
 - When averaged over Pacific storm track entrance and exit, and Atlantic storm track entrance and exit, and all Northern Hemisphere (mainly land areas) between 30-65 N, trend based on 20CR most consistent with Obs
- Based on 20CR (full reanalysis):
 - Pacific storm track trend ($+2.6 \pm 12.2\%/40\text{-yr}$) not significant
 - Atlantic trend ($+13.0 \pm 7.1\%/40\text{-yr}$) is significant
 - NH trend ($+6.7 \pm 6.0\%/40\text{-yr}$) is significant

V_{1df} trends (1958/59-1998/99) based on full reanalyses

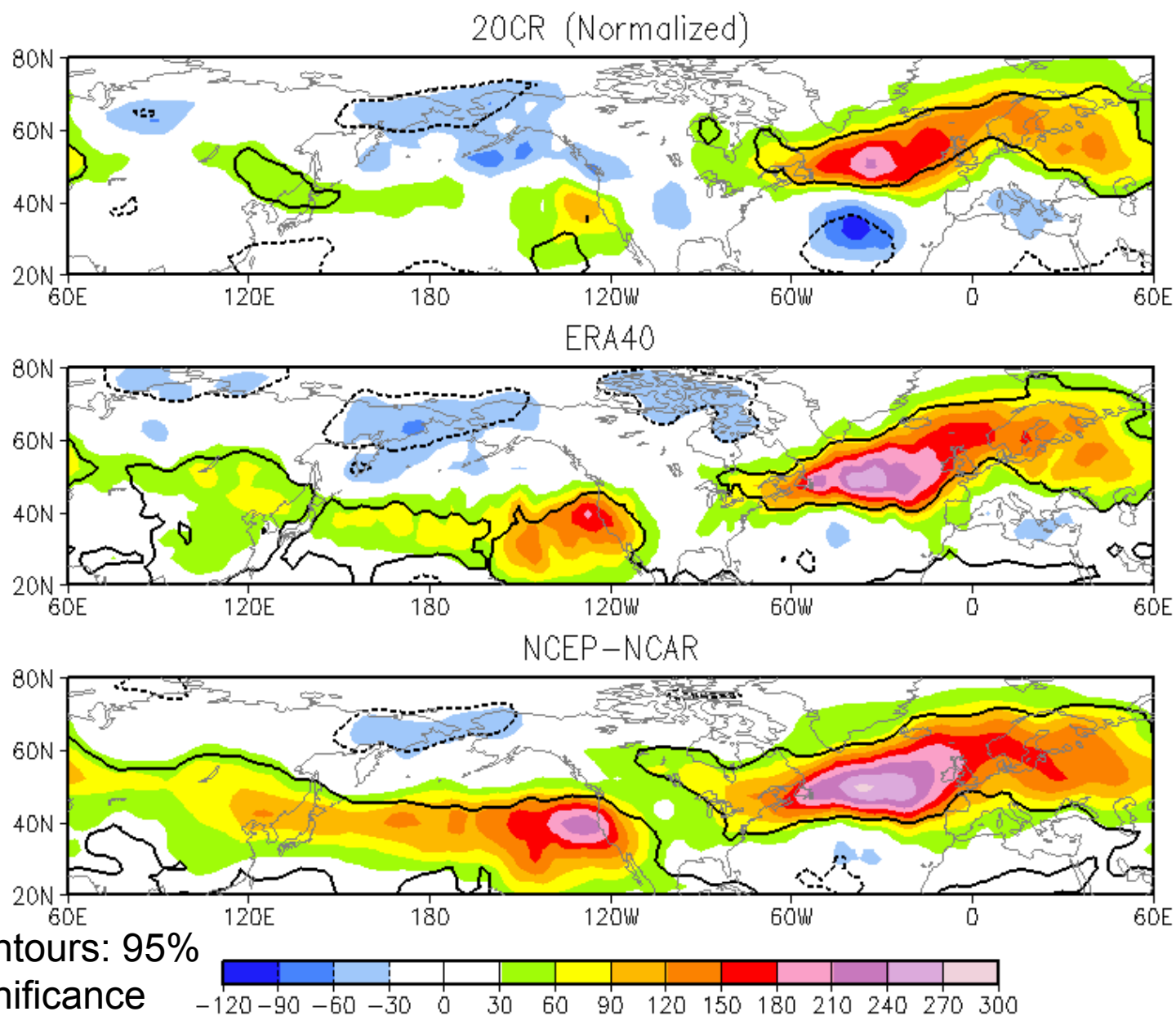
%-trend over 40-yr	Pacific	Atlantic	NH
20CV (most likely)	2.6±12.2	13.0±7.1	6.7±6.0
ERA40 (probably biased high)	12.7±11.6	20.4±7.9	15.6±6.3
NNR (extremely biased high)	28.7±12.2	29.2±9.7	27.0±7.5

Black: Significant at 95% level

Green: Not significant at 95% level

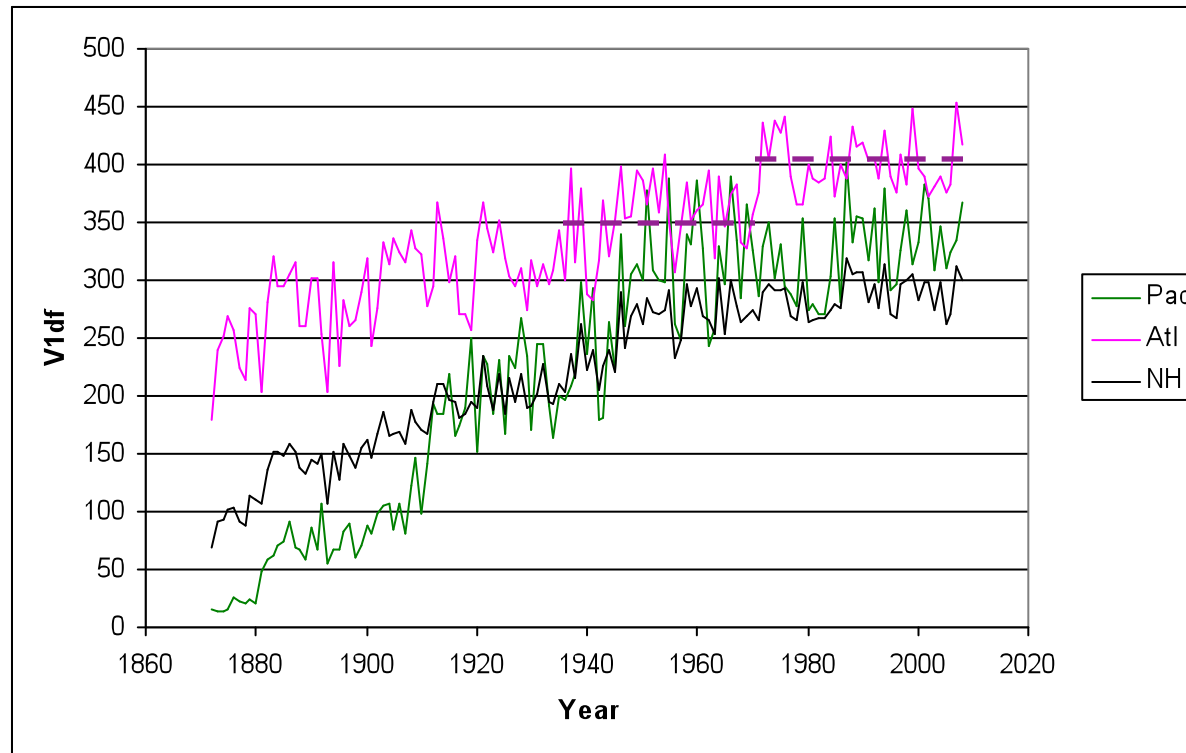
(95% confidence limits tabulated above)

Difference in V1df between 1989/90-98/99 and 1959/60-68/69



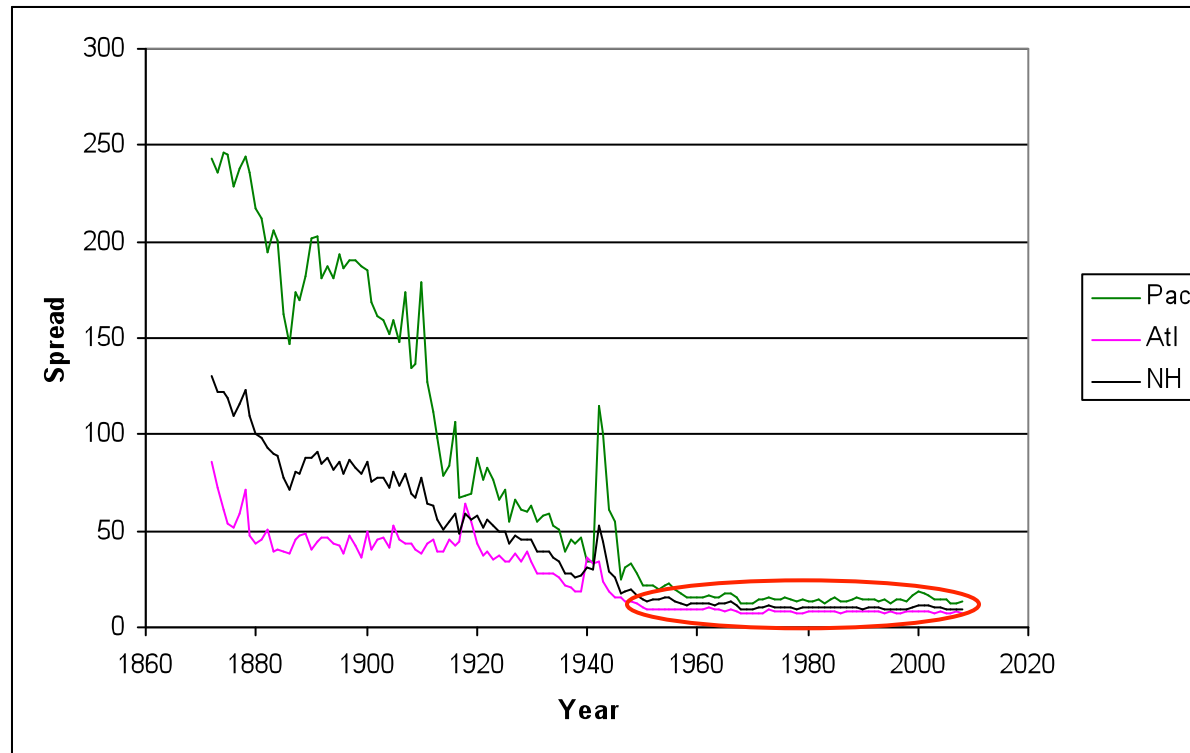
How about the entire 20CR record?

V1df for DJF of 1871/72 to 2007/08



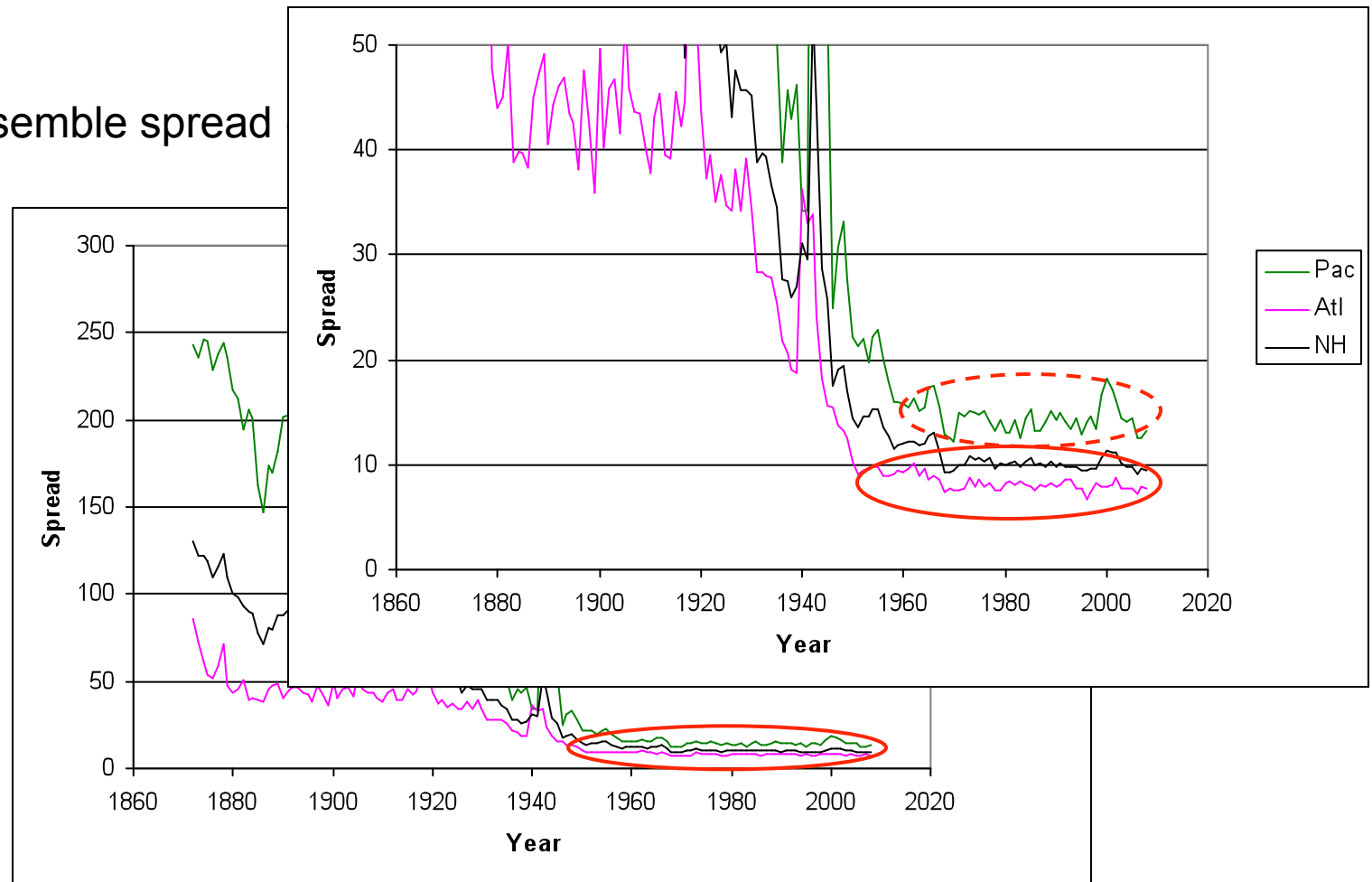
Atlantic storm track jumped right after 1970?
Real or artifact?

Ensemble spread (variance) averaged over respective regions



Quantitative values of ensemble spread (as well as spatial pattern) do not change much between 1950-2008:

Ensemble spread



Quantitative values of ensemble spread (as well as spatial pattern) do not change much between 1950-2008:

- Quality of 20CR analyses over Atlantic consistent since 1949/50
- Quality of 20CR analyses over Pacific consistent since 1957/58

- Conclusions

- Trends in storm track activity (in terms of 300 hPa filtered variance statistics) have been compared between various reanalysis data sets and rawinsonde observations for DJF of 1958/59 to 1998/99
 - Trends derived from 20th Century reanalysis data are most consistent with those derived from observations
 - Pacific storm track exhibits no significant trend
 - Atlantic storm track trend +13% over 40 years
 - Northern Hemisphere storm track trend +7% over 40 years
 - ERA40 trends exhibit some positive biases
 - NCEP-NCAR reanalysis trends are severely biased
- Storm track activity over the entire 20CR period (1871-2008) have been examined
 - Jump in Atlantic storm track soon after 1970 appears real
 - Quality of 20CR analyses over Atlantic consistent starting from 1949/50
 - Quality of Pacific analyses consistent starting from 1957/58

- Ongoing and future work
 - Performing similar analyses comparing variances based on surface ship SLP observations with various reanalysis data
 - Examining statistics of significant cyclones (SBU graduate student Albert Yau)
 - Deep cyclones
 - Explosively deepening cyclones
 - 1979 to 2002 using ERA-Interim as reference
 - Lagrangian rather than Eulerian statistics
 - Different basins: Atlantic, W. Pacific, E. Pacific
 - Examine trends in fall and spring
 - What led to upward trend in winter Atlantic and NH storm tracks during 2nd half of 20th Century?
 - Examine mean flow trends
 - Examine CMIP5 historical simulations to see whether similar upward trends can be found in model simulations

The End

Questions and comments?

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